DIGITISED METRIC CAMERA PHOTOGRAPHY: ACCURACY AND COMPLETENESS OF CARTOGRAPHIC PRODUCTS

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ABSTRACT

This paper presents an evaluation carried out on the map information that has been extracted from analogue and digitised Metric Camera photographs, in relation to accuracy, information content and completeness of cartographic products.

Results suggest that although the geometric and cartographic accuracy are within the required standards, the information content of the imagery itself has proved the limiting and dominant factor.

The absence of certainty about very significant proportions of the information set suggests that the present specification is not completely suitable for map compilation and map revision.

1. INTRODUCTION

Restitution of analogue space photographs was performed by setting up stereomodels entirely on the analytical stereoplotter Kern DSR1 and plotting was carried out on the Kern GP1 graphics peripheral (Meneguette, 1985).

Digitised photography was evaluated using the digital monocomparator plotter (Meneguette, 1988), which comprises a suite of computer programs using an I²S model 75 image processor linked to a VAX 11/750.

Maps generated from space photography in analogue and digitised form at the scales of 1:200.000, 1:100.000, and some at 1:50.000 scale, were compared with existing maps for the test areas, in order to assess the amount and quality of cultural features for both topographic mapping and map revision.

This work was carried out at University College London (UCL) and financial support was given by the Brazilian Research Council, Conselho Nacional de Desenvolvimento Cientifico e Tecnologico (CNPq).

1.1 Existing maps

Various maps were available for this study, covering the areas of interest in France and Libya.

France has a wide selection of maps, though not all of them cover the area of study, which is located to the north of Marseille. Maps at 1:25.000, 1:100.000 and 1:200.000 scales have been utilised.

Libya is less fortunate, and initially only maps compiled in 1962 were available, some of which cover the study areas of Zawiyat Al Majhub and Misratah. Later on in this study, a more recent map, compiled in 1979 was supplied for the Misratah region.

However, all of these maps are presented in the conventional graphical form. In order to obtain a digital version of the maps, it was necessary to vector digitise them, and then display the maps on a high resolution colour monitor.

1.2 Newly compiled maps

Maps in digital and graphic form have been generated for areas in France and Libya. All the newly generated maps from space photography have been kept in digital form by writing files to floppy disks and magnetic tapes. The content of such maps can be seen by displaying these on a colour monitor, as map images, or alternatively they can be drawn point-by-point on the graphics planes.

These maps can be overlaid with the imagery, precisely registered, or simply shown on the screen, together with a grid or any annotations. The digital maps displayed on the colour monitor can also be photographed or line graph maps be plotted.

Maps generated for the French area have been derived from metric camera photographs, as well as from Landsat Thematic Mapper images.

The Libyan area covered by metric camera photographs has been plotted at 1:50.000 scale in order to allow direct comparison with the existing map. Another region has been plotted at 1:100.000 and comparisons have been made between the newly compiled map and the existing maps dated from 1962 and 1979.

Originally, maps in graphic form were plotted in colour, in an attempt to produce a

similar version to the existing maps. Therefore the differentiation on the newly compiled between features of distinct classes (such as roads, railways and rivers) could be made by associating the colour scheme to that shown on the existing map.

For maps plotted on the analytical stereoplotter, several layers of data were considered, each of them upholding specific information, such as road network, drainage features, vegetation, etc. Plots were made on Ozatex plastic, as well as on scribe coat, the latter being a more stable material.

2. CARTOGRAPHIC ACCURACY OF MAPS

Coordinates of control and test points have been measured on existing and newly compiled maps using an electronic digitiser. Further checks were carried out by employing a technical (engineer's) ruler.

Sets of (X,Y) coordinates were compared and the root mean square error (rmse) of the residuals have been computed. Results presented for each of the test areas have indicated that ground control plays a very important role in the final accuracy values.

According to the map accuracy standards, the results obtained for control points in most cases fall within the accuracy required for the scale of 1:100.000, when plots from the metric camera are considered. For plots generated from the thematic mapper, standards are fullfilled for scales ranging from 1:50.000 to 1:100.000.

For test points, however, accuracy standards for scales smaller than 1:100.000, and in some cases 1:200.000, are reached by plots generated from metric camera photography.

Another form of cartographic product generated in this study has been image maps. Landsat imagery and digitised photography covering the French area have been utilised for the generation of image maps.

Digital image maps have been further improved by overlaying data, which has been extracted from existing and newly compiled digital maps. Enhancement techniques have as well been applied to the imagery.

Results of applying geometric correction have shown that average errors between 0.39 pixel and 0.24 pixel, which correspond to 11.7 metres and 7.2 metres, can be obtained from TM imagery. Ideally, this would be enough to reach accuracy standards of maps at the scales of 1:25.000 and 1:50.000.

For the digitised metric camera photograph, however, results of 0.52 pixel or 10.4 metres have been obtained, because the image had been subsampled previous to the warp. Nevertheless, accuracy standards for mapping at 1:50.000 scale should be fullfilled.

Although the average errors could indicate a rather optimistic allowable map scale for topographic mapping applications, this would be misleading, since only small areas of a whole image were considered and a few points were utilised.

3. INFORMATION CONTENT OF MAPS

Similar results to those of other workers have been found in the present study, following a certain trend towards an increase in detectability as a function of the spatial resolution, but mainly due to the multispectral capability of the sensor employed.

3.1 French Area

Metric camera photographs, covering the European test site, near Marseille, have been utilised for the generation of maps at 1:100.000 scale. One of these maps has been reduced in a photocopier to the scale of 1:200.000 scale, in order to present an illustration with reference to an existing map.

The resulting maps show cultural and drainage features such as roads, railways, reservoirs, airports, rivers, dams, ponds, stadium and car race tracks, canals, lakes, and industrial sites, with tanks and large buildings. Tracks can be depicted on the imagery, depending on the surroundings. Thus, if contrast is poor even roads may partly disappear. Motorways have shown up very well in the imagery, allowing plotting to be done on most of the extent, although, as has been shown on the plot at 1:200.000 scale, some parts are missing. This has also been noticed for other features, mainly in those areas where there is high relief and therefore the presence of shadows.

It is also very difficult to establish the boundaries of the urban areas, but some main roads can be depicted in the street pattern of the towns. Buildings can also be seen and extracted from the imagery.

A large number of relevant features can be detected on the photographs but very significant proportions of the information are missing or do not appear sufficiently clear, indicating that the present specification is not suitable for reliable map revision at 1:100.000. Maps at 1:200.000 and 1:250.000 scales could be generated, but still they would not contain all of the information required at such scales.

With respect to the digital imagery, when looked at on the colour monitor at full resolution, the Thematic Mapper imagery appears to have much more detail than the metric camera photographs. In addition to that, the multispectral capabilities of the Thematic Mapper add a further advantage over the space photographs.

This first impression is confirmed by comparing the plotting excerpts generated from both sources of data, by using the digital data capture of the analytical stereoplotter and of the digital mono comparator plotter respectively.

The data captured by employing the digital mono comparator plotter can be displayed on the imagery by means of the data overlay facility, so as to allow checking to be carried out and omissions or mistakes corrected. These newly generated maps can also, and have been, compared with the existing IGN maps dated from 1979 and 1983.

Enhancement techniques applied to various band combinations of space imagery allowed certain features to be visualised more easily. Enhancement, however, does not add any further information than that which already exists in the imagery; it merely makes the task of interpretation become easier for the human operator. It is worth mentioning that visual evaluation of image quality is a very subjective process and usually a certain amount of trial-and-error is required before a particular image processing approach can be considered.

In summary, colour combinations of the Landsat Thematic Mapper which yielded the best results were: bands 7, 4 and 3; and bands 4, 3 and 2. The enhancement techniques, rather simple but effective, were a linear contrast stretch and a space variant contrast stretch. Another method, which proved very useful, mainly in highly vegetated areas, was a technique developed by this author, which employs vegetation indeces (Dowman et al, 1986).

3.2 Libyan Area

When the existing 1:50.000 maps of the Libyan area are compared with the newly generated maps from metric camera photographs, the amount of information that is shown is remarkable, and its importance is even greater when it is considered that, initially, the only available maps for that area date from 1962.

Many changes have occurred in this region since then, thus the details plotted show many new features not included in the existing maps, such as jetties in the harbour, large buildings, roads and tracks, some of which appear on the more recent 1971 map.

Land parcels correspond very well to the existing farm boundaries of the outdated maps, the same applying to some of the roads, which already existed. New roads, however, have been built adjacent to the existing ones and have been plotted with difficulty. The only problem, as far as interpretation is concerned, is in the differentiation between some of the fences and streets or tracks, which look very similar.

The spatial resolution of the MC photographs is sufficient to enable the detection of a large number of very relevant features for those wanting to monitor and record change in the rural environment. On the other hand, the absence of certainty about very significant proportions of the information set suggests that the present specification is not completely suitable for map revision (Dowman et al., 1985).

4. COMPLETENESS OF MAPS

Quantitative tests have been performed on maps at various scales, by selecting some samples of cultural features normally found at all scales and comparing the extent of these on the newly generated maps with the amount found on the existing maps.

Comparisons have been carried out using maps both in digital and graphical form for the French area, and only graphical form for the remaining regions.

In the case of comparison of graphical output, the method adopted has been to overlay the newly derived maps, plotted on transparent material such as tracing paper and Ozatex plastic (0.005 inch thick), onto the existing maps. The inverse procedure has also been adopted so as to allow double check to take place.

Lengths of roads have been read off maps directly, when available, otherwise a map measuring device has been utilised and readings (cm) were transformed into the particular scale of the map being measured.

Digital maps have also been compared by several methods. One of them involves the display of cartographic images through the graphics planes, which allows different colour combinations. By employing this method, in which each type of feature is considered at a time, both maps, namely the vector digitised map from the existing map and the newly digitised map from the imagery, can be seen simultaneously.

Since different colours are assigned to each of the data being displayed, it is very easy to know which string belongs to which data set. When corresponding lines present in both maps are displayed at the same location, there is a change of colour, which does not necessarily indicate a match. Care had to be taken when selecting the samples, so that surrounding lines could not interfere with the ones being considered.

Separate tables were produced for each of the areas and sensors considered; such tables contain the lengths of linear features, given in kilometres, for measurements made on existing maps and newly compiled maps. The latter has been subdivided into those features that have been correctly and incorrectly classified. The difference between the length of the correctly classified features, which were measured on newly compiled and existing maps, has been considered the amount of missing information.

Results are presented as percentage when comparing lengths of features present on existing maps and those plotted from space imagery. Finally, a more general table was made in which percentage figures are given with respect to each of the classes of features considered.

4.1 French area

Methods mentioned previously have been used in order to obtain the length (km) of linear features of five main classes:
- motorways;
- main roads;
- other roads, which have been subdivided into regularly maintained and not regularly maintained; among the regularly maintained roads, a distinction was made between those with 2 lanes or more and 2 narrow lanes or less;
- railways, with two subclasses: double-track and single-track;
- water bodies, which have been subdivided into rivers, minor rivers and irrigation schemes, boundary of lakes, sea coast and canals.

It is worth mentioning that there are two situations involving the Metric Camera plots. One of them is that a Metric Camera plot ("MC 100") has been generated at 1:100.000 and recorded digitally, thus, plotting can be carried out at any scale, such as 1:200.000.

On the other hand, another Metric Camera plot ("MC 200") has been generated at 1:100.000 scale and has been reduced to 1:200.000 scale in a photocopier.

Thus, there are at least two possibilities of presentation concerning the scale of maps, this is why two separate results will be presented in this section.

By taking the lengths of features measured on the IGN map as 100%, the percentage values have been computed (Tables 1 and 2) for the length of features on maps generated from Metric Camera ("MC 100" and "MC 200") and Thematic Mapper imagery ("TM 100").

Completeness results (%) of 1:100.000 scale plots from the space imagery covering the French area, as compared to existing maps at scales of 1:100.000 (IGN) and 1:200.000 (Michelin), are presented in Table 3. Only correctly classified features have been considered and individual results of each of the plots are dealt with.

In Table 3, feature type referred to as "minor roads" include the regularly and not regularly maintained roads, while the category "railways" includes both double- and single-track subclasses. "Water bodies" include all those features listed as rivers, minor rivers and irrigation schemes, boundary of lake, sea coast and canals.

Table 1
Completeness (%) of 1:100.000 MC and TM plots of French area with respect to IGN 1:100.000 map compiled in 1983.

feature type	MC plots (MC 100 / MC 200) classified correct	incorrect	missing	TM plot (TM 100) classified correct	incorrect	missing
motorways	88,37/88,37	0,00/0,00	11,63/11,63	100,00	0,00	0,00
main roads	65,57/49,18	9,84/8,20	34,43/50,82	88,52	3,28	11,48
other roads						
regularly maintained						
2 or > lanes	36,11/38,88	0,00/0,00	63,89/61,11	97,22	0,00	2,78
2 narrow lanes	10,79/11,51	0,00/0,00	89,21/88,49	51,80	0,72	48,20
not reg. maintained	47,37/52,63	0,00/0,00	52,63/47,37	68,42	0,00	31,58
railways						
double-track	31,25/25,00	0,00/0,00	68,75/75,00	84,37	0,00	15,63
single-track	30,00/30,00	0,00/0,00	70,00/70,00	0,00	0,00	100,00
water bodies						
rivers	54,17/25,00	0,00/0,00	48,83/75,00	79,17	0,00	20,83
minor rivers & irrigation schemes	0,00/0,00	0,00/0,00	100,00/100,00	0,00	0,00	100,00
lake boundary	95,83/95,83	0,00/0,00	41,67/41,67	95,83	0,00	41,67
sea coast	100,00/100,00	0,00/0,00	0,00/0,00	100,00	0,00	0,00
canal	100,00/100,00	0,00/0,00	0,00/0,00	100,00	0,00	0,00

Table 2
Completeness (%) of 1:100 000 MC and TM plots of French area with respect to Michelin map at 1:200.000 scale.

feature type	MC plots (MC 100 / MC 200) classified correct	incorrect	missing	TM plot (TM 100) classified correct	incorrect	missing
motorways	95,00/95,00	0,00/0,00	5,00/5,00	100,00	0,00	0,00
main roads	72,73/54,55	10,91/9,09	27,27/45,45	98,18	3,64	1,82
other roads						
regularly maintained						
2 or > lanes	65,00/70,00	0,00/0,00	35,00/30,00	100,00	0,00	0,00
2 narrow lanes	18,75/20,00	0,00/0,00	81,25/80,00	90,00	1,25	10,00
not reg. maintained	100,00/100,00	0,00/0,00	0,00/0,00	100,00	0,00	0,00
railways						
double-track	31,25/25,00	9,37/0,00	68,75/75,00	84,37	0,00	15,63
single-track	30,00/30,00	0,00/0,00	70,00/70,00	0,00	0,00	100,00
water bodies						
rivers	72,22/33,33	0,00/0,00	27,78/66,67	100,00	0,00	0,00
minor rivers						
& irrig. schemes	0,00/0,00	0,00/0,00	100,00/100,00	0,00	0,00	100,00
lake boundary	100,00/100,00	0,00/0,00	0,00/0,00	100,00	0,00	0,00
sea coast	100,00/100,00	0,00/0,00	0,00/0,00	100,00	0,00	0,00
canal	100,00/100,00	0,00/0,00	0,00/0,00	100,00	0,00	0,00

Table 3
Completeness (%) of cultural features on 1:100.000 plots as compared to IGN 1:100 000/Michelin 1:200.000 map of the French area.

surface features	completeness (%) MC 100	MC 200	TM 100
motorways	88,37/95,00	88,37/95,00	100,00/100,00
main roads	65,57/72,73	49,18/54,55	88,52/98,18
minor roads	35,41/70,94	38,91/72,50	71,46/97,50
railways	30,62/30,62	27,50/27,50	42,16/42,18
water bodies	70,00/74,44	64,17/66,67	75,00/80,00

Therefore, for the French area, completeness results of 1:100.000 scale plots from the space imagery, as compared to existing maps at 1:100.000 (IGN) and 1:200.000 scale (Michelin), have indicated that reliable mapping could not be carried out at 1:100.000 scale. This is due to the low percentage of features present in the newly plotted maps.

If values given in the tables presented are considered, not even mapping at 1:250.000 scale would be done adequately. For the thematic mapper improved results over the metric camera were obtained.

However, if some restrictions were made concerning the feature types to be considered in the evaluation, mapping could be achieved from the thematic mapping imagery at both 1:100.000 and 1:200.000 scale, while for metric camera plots, still 1:250.000 scale would be more adequate.

4.2 Libyan Area

The newly compiled plot of the Zawiyat Al Mahjub area in Libya, at the scale of 1:50.000, has been selected for this quantitative test, which results are shown in Table 4. The same techniques applied to the French test have been adopted here.

Here four main classes have been considered, since they are more adequate to the region in question. These classes are:
- hard surface, all weather roads, which have been subdivided into roads with 2 or more lanes (5-metre wide) and those with one single lane (3-metre wide);
- loose surface, all weather roads, for which the same subclasses as the former class apply;
- loose surface, fair or dry weather;
- sea coast;

A fifth class had been considered, which

Table 4
Completeness (%) of 1:50.000 plot from metric camera for the Zawiyat Al Mahjub area as compared to the 1962 map at 1:50.000 scale.

feature type	classified correct	incorrect	missing
hard surface road (all weather)			
2 or > lanes wide	100,00	0,00	0,00
1 lane wide	0,00	0,00	100,00
loose surface road (all weather)			
2 or > lanes wide	0,00	0,00	100,00
1 lane wide	90,48	4,76	9,52
loose surface road			
(fair or dry weather)	15,38	0,00	84,62
sea coast	100,00	0,00	0,00

includes tracks and trails, but the difficulty of differentiating these from field boundaries and fences precluded a reliable quantitative test.

An option would have been to overlay the newly compiled map onto the existing map and compare the lineaments, so that those which match would be taken.

However a great deal of lines have been detected and plotted from the metric camera photographs, which are not shown on the 1962 map. Therefore, to consider only those lines that actually correspond to the ones plotted on the existing map could not be representative of the potential of the space photographs for this type of linear feature.

Similar conclusions to the French area are achieved concerning the Libyan area, for which metric camera plots were prepared at 1:50.000 and 1:100.000 scales. Mapping at medium scales should therefore not be carried out from this source of data, since the amount of missing information would be over the accepted limits, even for developing countries. Space photography could be used when establishing priority areas for map revision, but not for reliable topographic mapping.

5. CONCLUSIONS

Cartographic accuracy, cultural information content and completeness results of space imagery evaluated in this study, as compared to existing maps at 1:200.000, 1:100.000 and finally, at 1:50.000 scale, have been presented.

Results have been given for each of the test areas, in France and Libya, and a common point has been made clear: although the geometric and cartographic accuracy are within the required standards, the information content of the imagery itself which has proved the limiting and dominant factor.

According to this author's point of view, more and more research should be carried out on the topic of cartographic accuracy and information content, since not a great deal of work is available in the literature.

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